



Space Program Testing in the NASA Glenn Research Center 10x10 SWT

Historically, testing in the 10x10 Supersonic Wind Tunnel involved aeronautics type testing including testing of Supersonic Propulsion Components such as inlets and nozzles, Propulsion System Integration, Full-scale Jet and Rocket Engines, Aerodynamic Force and Moment testing, Sonic Boom Mitigation and the investigation of Advanced Aircraft Models.

The New Space Directive(s) called for new areas of testing. Two interesting and challenging tests were proposed for the 10x10 SWT, the Inflatable Aerodynamic Decelerator (IAD) and the Mars Science Lab (MSL) Flexible Parachute. This presentation highlights those tests and plans for future testing in the 10x10 SWT.



Space Program Testing in the NASA Glenn Research Center 10x10 SWT

Prepared by **Matthew Ogorzaly**
Electrical Test Engineer, Jacobs Technology, Inc.
c/o NASA Glenn Research Center
NASA Contract NNC05CA95C

Presented by **Edward Becks, P.E.**
Test Engineering Services Manager, Sierra Lobo, Inc.
c/o NASA Glenn Research Center
NASA Contract NNC05CA95C

110th STAI Meeting, Tel Aviv, Israel; October 26-28, 2008



GRC 10x10 SWT

- Historically, testing in GRC's largest wind tunnel involved primarily traditional aeronautics type testing
 - Supersonic Propulsion Components such as inlets and nozzles
 - Propulsion System Integration
 - Full-scale Jet and Rocket Engines
 - Space Shuttle Development
 - Aerodynamic Force and Moment
 - Sonic Boom Mitigation
 - Advanced Aircraft Models
 - Missiles



GRC 10x10 SWT

- New Space Directive calls for new areas of testing
 - Limited facilities available to accommodate new specialized tests
 - 10x10 SWT was proposed as a viable facility for this type of testing
- Two interesting and challenging tests were subsequently assigned to GRC
 - Inflatable Aerodynamic Decelerator
 - Mars Science Lab Flexible Parachute

Inflatable Aerodynamic Decelerator

Advanced missions to Mars will need aerodynamic decelerators that can be deployed at high Mach numbers ($2.5 < M < 5$).

Inflatable Aerodynamic Decelerators (IAD's) are a promising option to fill this need.

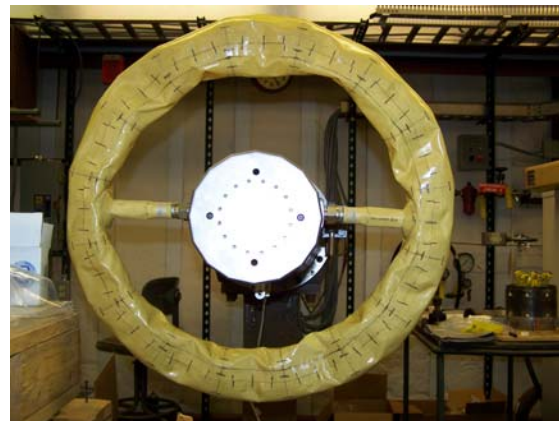
The type of IAD being tested at the GRC 10x10 SWT is known as a tension cone: an inflatable torus attached to the aeroshell by a single-surface textile tension shell.



Tension Cone IAD

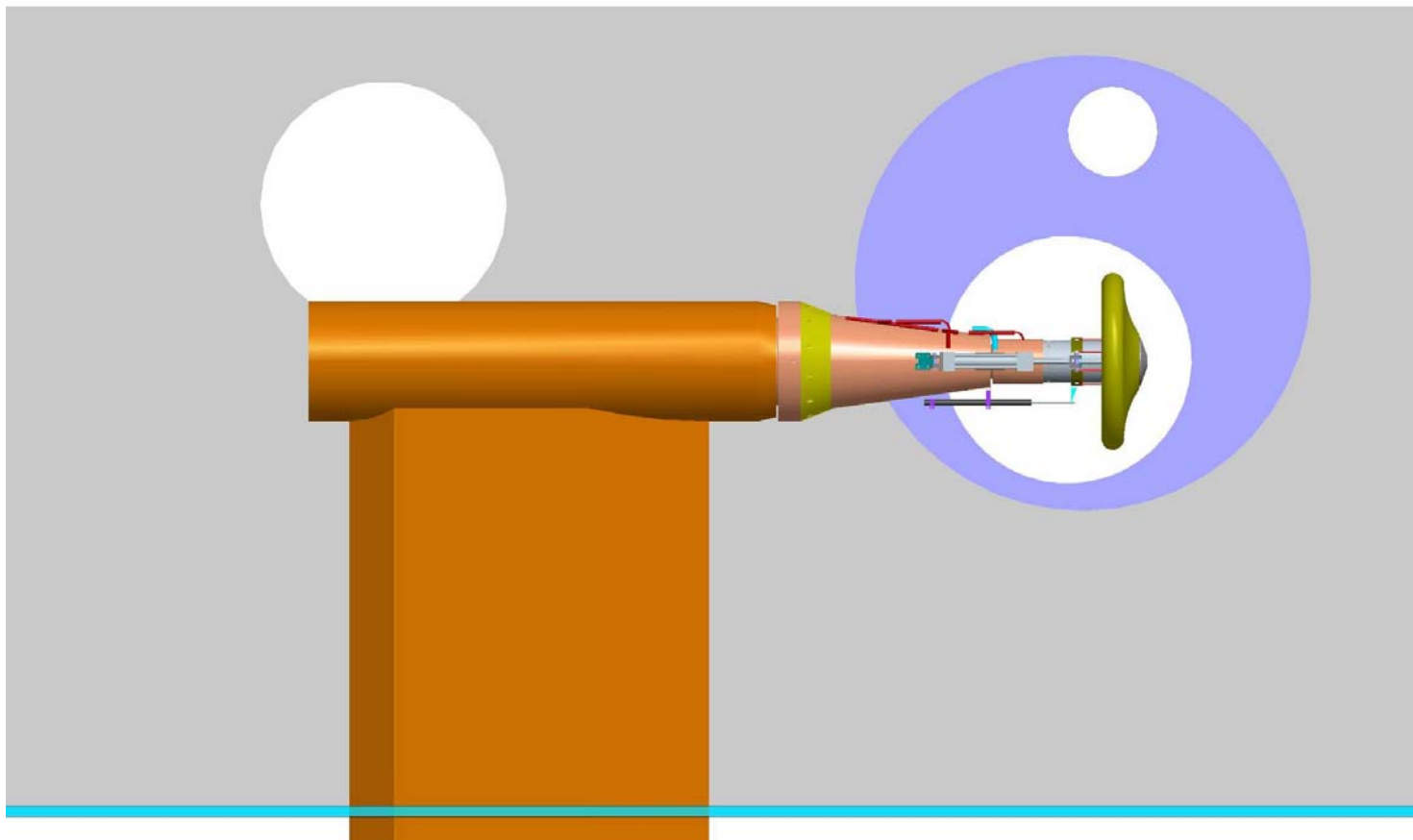
GRC 10x10 SWT

- IAD Tension Cone



GRC 10x10 SWT

Tension Cone IAD Test Setup at GRC 10x10 SWT





GRC 10x10 SWT

Tension Cone IAD Test Research Objectives

Qualitative Objectives:

- Determine flow stability
- Investigate aeroelastic stability
- Characterize deployment (inflation) from a stowed state

Quantitative Objectives:

- Obtain static aerodynamic characteristics
- Determine shape and position of the shock(s)
- Characterize time history of unsteady forces and moments during deployment (inflation)
- Determine inflation pressure required to eliminate localized wrinkling on the torus
- Determine minimum inflation pressure required to maintain the torus in a non-buckled state
- Determine minimum inflation pressure required to re-deploy from a partially inflated state

GRC 10x10 SWT



Tension Cone IAD Inflation

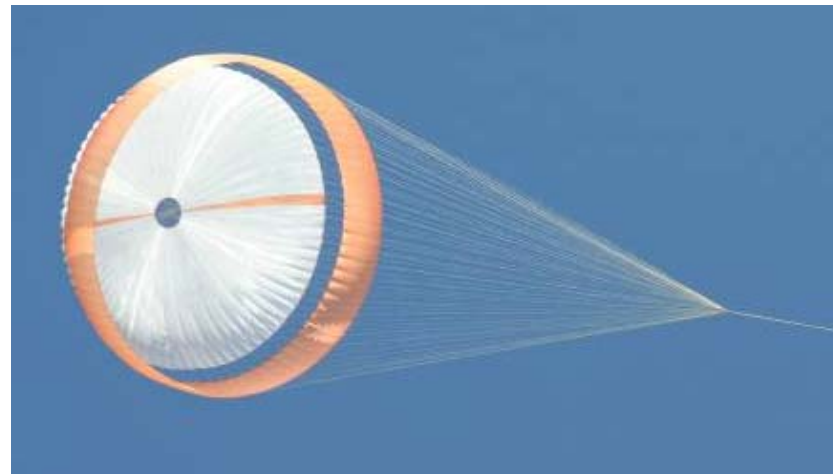
Mars Science Lab Flexible Parachute

- The Mars Science Laboratory mission will use a heritage Viking design DGB (disk gap band) parachute as part of the EDL phase of the mission.
- This parachute configuration has extensive flight heritage over a large range of conditions ($0.5 < M < 3.3$, $300 \text{ Pa} < Q < 988 \text{ Pa}$).
- The MSL baseline is to use a 21.5-m version of the Viking DGB parachute deployed at Mach 2.2 and 700 Pa
- This is larger in size than the existing flight qualification of the 16.1m DGB from the Viking BLDT (balloon launched decelerator test) program and Viking Lander 1 & 2 missions.
- As a result, there is a need for a delta qualification for size of the MSL 21.5m parachute over the existing Viking BLDT 16.1m qualification



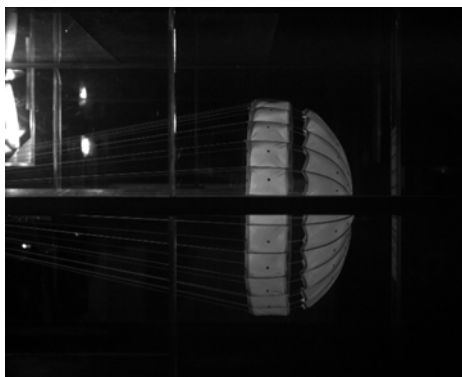
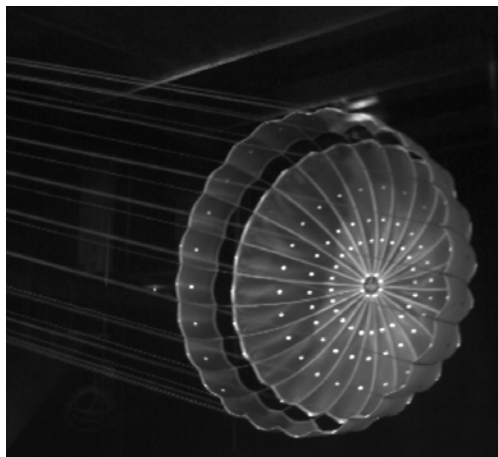
GRC 10x10 SWT

- In order to address the issues associated with supersonic operation of the MSL parachute, the flight system has engaged in a CFD-FSI analysis effort to improve understanding and retire residual risk pertaining to supersonic operation of 19.7m versus 16.1m DGB.
- CFD-FSI tools are being developed for the MSL parachute activity to aid in the development of the physical understanding of supersonic operation of DGB parachutes for Mars type deployment conditions.
- In order to rely on the predicted physics generated by these tools, experimental data must be used to validate the CFD-FSI techniques.
- As no such data currently exists, an experimental, subscale wind tunnel test program has been specifically designed to validate the predictive capability of the CFD-FSI techniques.



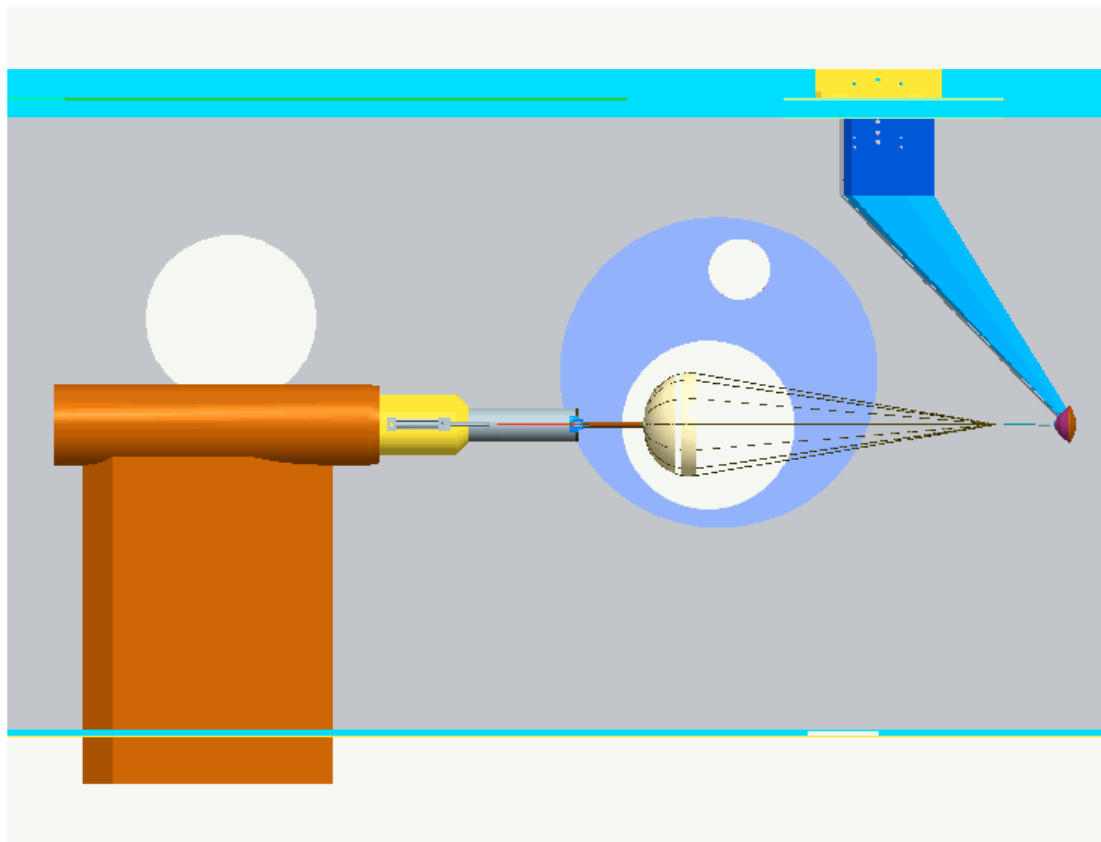
GRC 10x10 SWT

- MSL Flexible Parachute



GRC 10x10 SWT

Flexible Parachute MSL Test Setup at GRC 10x10 SWT





GRC 10x10 SWT

4% Scale MSL Flexible Canopy Entry Objectives

- Assess the Mach and Re dependence of parachute flow field in supersonic, unsteady, Mars-type deployment conditions.
- Design experiment to validate Fluid-Structure-Interaction (FSI) predictions of the interaction of the unsteady turbulent capsule wake with flexible parachute.
- Provide a quantitative spatially resolved experimental dataset of velocity, fabric motion and canopy loading to validate the FSI predictions of the experiments.
- Provide high speed measurements of density contours (shocks), (shadowgraph), velocity field (PIV – Particle Image Velocimetry), drag (load cell) and fabric motion (Photogrammetry) in the experimental flow field to compare to FSI predictions.

GRC 10x10 SWT



MSL Parachute Constrained Deployment



GRC 10x10 SWT

Special Thanks to:

- Juan R. Cruz, Ph.D.
Atmospheric Flight and Entry Systems Branch
NASA Langley Research Center
- Anita Sengupta, Ph.D.
Mars Science Laboratory
Jet Propulsion Laboratory



GRC 10x10 SWT

Conclusions:

- Both the initial IAD and MSL tests have proven successful, as evidenced (to an extent) in the imbedded video clips. However, at the time of this presentation no specific test data has been authorized for release.
- Another series of tests is planned later this year and it is hoped future STAI presentation will include these results.
- Questions?